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INTERNAL MORPHOLOGY OF THE AMERICAN CATTLE TICK

By W. E. Allen

WITH FOUR PLATES

Introduction

Although in the present investigation the external morphology was carefully studied, that ground has been already so well covered that further discussion is unnecessary and the present paper is concerned only with the details of internal morphology. The aim has been throughout to establish each point by examination of at least ten specimens. *Boophilus annulatus* Say was the form studied but two specimens each of *Haemaphysalis leporis-palustris* (Packard) and *Amblyomma americanum* Koch were also dissected. It may be of interest to note that the internal structure of the former agreed very nearly with that of *Boophilus;* in the latter the primary reproductive system was almost identical, while the digestive tract differed most in the irregularity of its branching.

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TECHNIQUE

Dissection of the living animals and of those killed with chloroform gave the best results. Hot water (sometimes boiling) and boiling absolute alcohol were used in a few cases; the former is the better because it does not stiffen the tissues so much, but it is difficult to secure just the right temperature. Both are of value since they stiffen the organs enough so that the integument can be removed without serious spreading. The alcohol has the further advantage of fixing some tissues so that they can be quickly sectioned, though the percentage of good results from such fixation was small.

Dissection was usually begun by taking an engorged tick between the tips of the thumb and forefinger of the left hand; then with a sharp pair of fine scissors, a continuous cut was made around the posterior and lateral dorsal margins. If the cut is not continuous, it is almost impossible to avoid cutting or tearing some of the digestive caeca or Malpighian tubules, which protrude through even the smallest opening. After making this cut the specimen was immediately placed in physiological salt solution in a watch glass. The ventral integument was then firmly pressed against the bottom of the dish by a needle at the posterior margin, while the dorsal part was pulled upward and forward by another needle or fine forceps. The dorsal integument was now cut by either scissors or scalpel just behind the head-shield, leaving the internal organs exposed freely to further dissection.

In the study of the histology the greatest success was obtained by cutting off everything behind the second pair of legs and then removing the digestive caeca and Malpighian tubules from that part. This was done quickly and the tissues at once put into Carnoy's second solution (Lee, 1900: 64). The specimens were cut in paraffin; some at 10μ, others at 13μ to 17μ. A few specimens of the posterior part containing tubules and all were prepared in the same way, and individual tubules and diverticula were also given the same handling. All the tissues seemed to give good results by this method except the salivary glands, which were somewhat shrunken; even the integument cut well, though the mouth parts broke badly and spoiled some sections.

Some of the salivary glands were dissected out and fixed in liquid of Tellyesniczky, with after treatment according to Lee (1900: 50), and gave better results, especially in lessening of the shrinkage.

Some good results were obtained by Henning's mixture:

Concentrated Nitric Acid	16 parts
Chromic Acid, 0.5 per cent	16 parts
Corrosive Sublimate saturated in 60 per cent. alcohol	24 parts
Concentrated Picric Acid	12 parts
Absolute Alcohol	42 parts

Washed out after about twenty hours, in 70 per cent. iodized alcohol.

It does not seem to make the chitin cut any better, but I did find that it penetrated the chitin for an excellent fixation, so that the tissues withstood the strain of cutting pretty well. It is not of any use with a very much engorged tick, or with a dark-colored one, but it is a great help with some of the smaller specimens. Almost all sections of entire ticks and of the posterior parts were made after this treatment, and it should be added that it appears to put digestive caeca and Malpighian tubules in better shape for cutting than any other reagent tried.

For hand sections very good results were secured from formaldehyde specimens. For these a specimen was taken between the fingers and cut with the ordinary botanical razor. The chitin in formaldehyde specimens seems to be of a soft, leathery consistency and cuts quite readily in this way, but hardens again on dehydration. The formaldehyde specimens were especially valuable in working out details of the mouth-parts.

Haemalum and eosin was the stain used almost entirely for sections. Delafield's haematoxylin gave about the same results, and Grenacher's alcoholic borax-carmine was used in a few cases with fair success. Methylen blue was frequently used in dissections in order to differentiate the various minute structures, and was found extremely valuable in tracing the salivary duct.

Integument and Musculature

In general appearance, the integument is a semi-transparent, leathery covering of rather thick chitin, enveloping the entire animal and its appendages. The leathery character is maintained over the greater part of the surface but there are certain areas in which the skin approaches the exoskeleton of the crayfish in hardness and rigidity. These hardened areas may be enumerated as follows: dorsal head-shield of female, four posterior ventral plates of male, genital clefts of both sexes, and anal plates and appendages in all forms. The color in normal individuals is of a reddish brown in both sexes and in all stages of development; it is somewhat smooth and shiny, and is pierced by a considerable number of hairs. Beside the mouth-opening, anal and genital openings are present.

The integument is clearly composed of two easily separable layers (Figs. 1 and 2), an outer chitinous and an inner cellular layer. The chitin, which is secreted by the cellular layer, varies considerably in thickness in different specimens, in accordance with the degree of engorgement, and also in different parts of the body. In the engorged female the thickness is fairly constant between the extremes of 96μ and 108μ. A specimen which was only about half engorged, ranged from 126μ to 150μ on the dorsal surface and from 90μ to

120μ on the ventral surface. Exceptions occur in the case of the hard parts and particularly in the integument adjoining such hard parts; the latter may show a thickness of nearly 300μ. The head-shield and other plates of great hardness are considerably thinner than the integument generally. A cross section of the head-shield measures 21μ in thickness near the posterior border, 30μ near the middle, and 57μ at the median line near the anterior border, with a lateral thickness of 120μ at this point.

The surface of the chitin on an engorged tick is almost smooth (Fig. 2) except for the hairs, but the unfed female is quite rough on the outer surface (Fig. 1). This roughness consists of deep indentations about one-third the thickness of the whole layer giving a comb-like appearance in section. All gradations between this condition and the other may be found; fig. 1 represents about a middle stage. Apparently this is an arrangement for permitting rapid distension of the skin under the strain of engorgement. This would imply that there are really two layers to the chitin; a very thin outermost, hard, non-extensible layer which is therefore folded, and the thick layer which is sufficiently elastic to extend without folding. But any real structural difference is not evident. The thickness of the chitin everywhere in the unfed female is about 30μ. This shows that there is a very large increase in thickness of the chitinous layer during engorgement. Longitudinal striations faintly visible in sections of the chitinous layer may possibly indicate the successive layers of deposition.

In the male, the chitinous layer is about 24μ in thickness and its outer surface is smooth. Evidently, there is no need of corrugations since the male does not become engorged. The same layer in the larva has a fairly uniform thickness of 6μ in both dorsal shield and general surface, but the former has a smooth surface while the latter is indented as in the unfed female. The few nymphs studied were not normal as they were just ready to moult and transform into adults.

In all forms and in all cases the chitinous layer is almost colorless in thin sections. It shows a faint tinge of yellow over the main part of the body, with a slight tendency to red on its outer surface, and it has a reddish tinge in sections of all the hardened plates.

The inner layer of the integument, the hypoderm, is composed of cells varying in form with the condition of the animal. In the female the thickness of this layer varies from 10μ to 30μ; 15μ is, perhaps, the most common thickness. The form of the cells varies from columnar (Fig. 1), mainly in the unfed female to cubical or flat (Fig. 2) in engorged specimens. They are flat in both male and larva, where the thickness of the layer is 3μ and about 2μ respectively.

As to size of cells, the engorged female shows measurements anywhere from 15μ by 12μ to 33μ by 15μ; on several occasions the dimensions were about 18μ by 18μ. In the unfed female the extremes were 12μ by 9μ and 30μ by 6μ, the latter being the more usual.

The measurements of the nuclei in engorged specimens varied between 9μ by 9μ and 15μ by 12μ, most of them being about 12μ by 9μ. The nuclei were oval; ordinarily the greatest diameter of the nucleus was parallel with the greatest diameter of the cell but some cases were noticed where it appeared transverse. There was also a very large proportion of round nuclei observed. The nuclei are very prominent in the male and larva, especially in the latter where they are the most striking feature of the cellular layer. In both forms they are oval, about 6μ by 4μ, and lying with the long axis parallel with the long axis of the cell.

The cells of the female are finely granular in structure, staining very readily and strongly with haemalum and eosin. The cell membrane was, in all cases observed, very indefinite and difficult of demonstration. The nuclei are coarsely granular and stain very rapidly and heavily. A great many are seen with a few larger granules which might be called nucleoli. The nuclear membrane is distinct in some sections though never very prominent.

The main differences in the male and larva are that the nuclei and cytoplasm are better differentiated by the stain, the cytoplasm staining much more lightly, and that the nuclei are not so coarsely granular.

The hairs generally distributed over the body of the female are about 90μ long, tapering very regularly from 6μ in diameter at the point of insertion to the almost indistinguishable tip (Fig. 1). Their rounded bases are set in sockets or cups the rim of which may be flush with the surface of the chitinous layer of the skin or below it, in the unfed female far below. The bottom of the cup is continuous with a channel or canal running from it through the chitinous layer to the hypoderm or cellular layer. This canal is about the width of the base of the hair, and in the unfed female is empty and cylindrical, while in the engorged specimen it is frequently, if not always, flared at the bottom, with some of the hypodermal cells crowded far into it (Fig. 2). This appears to be due to the pressure from the engorged digestive tract and to the stretching of the chitinous layer caused thereby. No particular variations in size or structure of hairs on dorsal and ventral surfaces has been observed except that the hairs on the head-shield and other hard areas may be a little shorter; so many of the hairs of all kinds were broken that comparisons of this sort were difficult. Hairs of special function are described elsewhere, those here considered probably being purely tactile in function and not very highly sensitive at that. Most of those shown in sections are set perpendicularly in the cup, though the socket joint would give the impression that they might be found slanting in every direction. Since no muscular attachments are noticeable, this uniformity of position must be due to some mechanical principle in the formation of the joint. The hairs of both male and larva are essentially similar to the above in every detail of structure; the differences being that in both the bases of the hairs are constantly just about level with the surface of the chitin, the canals are all cylindrical and the hairs are proportionately smaller, about 5μ by 45μ in the male and 2μ by 24μ in the larva.

A large part of the inner surface of the integument gives attachment to the various muscles of the body. Muscles pierce the cellular layer by a few processes and are attached directly to the inner surface of the chitin into which the processes penetrate very deeply (Fig. 3). These insertions are so secure that the muscles break or tear apart but do not in any case leave bare the surface of insertion. The most prominent muscles are those which run directly across the body from dorsal to ventral integument. They are arranged in bundles, oval or circular in cross section, most of which are from 60μ to 100μ in diameter, the bundles forming an almost continuous row or partition lengthwise of the body and about 150μ in width. There are three of these partitions, two trending backward from near the posterior border of the head-shield, leaving about one-fourth the body to the outer side of each, narrowing and scattering somewhat in the posterior half and being connected at the ends by a scattered cross row about 300μ from the posterior border; the third row trends backward from the anal region to the same point. These muscles may be easily traced in the engorged tick by furrows on the outer surface. It might be stated here that these muscles as well as others observed are striated and apparently identical in structure with the common arthropod muscles. Two very long and slender muscles run from about the fourth pair of legs to the mouth parts, apparently to the mandibles, but the demonstration is not conclusive as to either origin or insertion. A considerable mass of muscle is attached to the back part of the head-shield and inserted in the mouth-ring. This is, of course, the mouth-ring retractor and its action has the double effect of retracting and at the same time tilting the mouth parts down, and anterior head-shield up, so that plenty of room is left for the insertion of the egg into the shell gland sac. These are all the important muscles not distinctly belonging to the anatomy of particular organs. The musculature of the male and larva has not been worked out.

MOTOR ORGANS AND MOUTH PARTS

The legs resemble very closely the general arthropod type with telescoping segments and intersegmental musculature. The integument of the legs has a hard, horny character as in the head-shield except for a short space at the joints where there is a thin, loose membrane of chitin to give mobility. The two tegumentary layers, chitin and hypoderm, are evident here as elsewhere. The integument in most segments is fairly smooth and regular except near the joints where there may be irregular thickenings or projections, both internal and external. This is especially true of coxa and trochanter. The most distal segment on the first pair of legs has some important modifications on its anterior dorsal surface. There are two ridged internal, chitinous thickenings and apparently three tympani, a larger, a middle-sized, and a smaller (Fig. 4). The first knob or ridge is a little more than half way out the segment with the larger tympanum just beyond it. Sections of this area show that it is a vesicle with a thin layer of chitin covering it and with three (perhaps four) hairs reaching from its floor almost to the membrane. In well-preserved specimens these hairs seem to vary slightly in length but the point is doubtful. There are also three or four papillae about half as long as the hairs. In the best specimen examined the only long hair visible measured 36μ in length and the two papillae about 12μ (Fig. 5). The vesicle is 48μ in depth by 54μ in width and the chitinous covering is 3μ in thickness. The hair, instead of being set in the floor with a socket joint, as are other hairs, pierces the chitinous layer there and penetrates directly to the cellular layer where there is a mass of cells, not distinguishable in structure from the usual hypoderm. The vesicle is entirely lined with chitin. In fact it looks as though the chitinous layers had been pulled apart leaving a blister-like cavity. The segment tapers quite rapidly from a point just proximal to this vesicle so that the vesicle is set at an angle of something like 35° to the axis of the segment. There seems to be no doubt that this vesicle is auditory and that the thin chitinous covering is a sort of tympanic membrane transmitting vibrations to the vesicular contents and so through the hairs to the sense cells. The smaller area appears from some points of view to be included in the larger. No sections of it have been secured but in surface view it looks much like the larger so far as the chitin is concerned (Fig. 4). It is oval, measuring about 24μ by 15μ. It bears externally two short hairs standing close together, each something over 15μ in length, and four or five papillae or very short hairs about 5μ in length. The middle-sized organ is about 18μ distad of the smaller which in turn is about 5μ distad of the larger. It has the same general appearance as the others as to its surface but it bears two hairs each about 20μ long and these only. They are also separated by quite an appreciable interval. The outline is oval, 30μ by 45μ. The function of the lesser organs is probably tactile. The ticks almost invariably hold the front legs up when walking, and they are only used for motor purposes when the animal is disturbed. The male has these organs the same as the female; but the larva, while having the auditory organ the same, lacks the distal organ and shows but one hair on the other.

The legs are pretty well supplied with jointed hairs similar to those on the body but smaller, not more than 60μ long in the female, where there are from fifteen to thirty to each segment showing some tendency to arrangement in rows and in pairs near the joints. In the male the hairs are much more numerous on the legs as well as on the body and they are more irregularly placed, though tending more to be in pairs near the joints. They are larger on the legs than on the body, most of them being 60μ long while those at the joints may reach 100μ or more in length. On the larval legs the hairs are few and scattering, commonly about 21μ long but with distal hairs 30μ to 45μ, the latter length being noted on the distal segment of the first pair of legs.

The legs are pretty well supplied with air. In the female two air tubes of comparatively large size extend almost if not quite the entire length of the legs.

The nerve supply of the legs is not well worked out. So far only the nerves to the first pair of legs have been traced, which are the most anterior lateral pair given off from the brain. They are about 30μ in diameter and, in the one slide showing clearly, appear as a bundle of fibers with scattering nuclei enclosed in a loose sheath continuous with that enclosing the brain.

The mouth-ring is made up by the fusion of upper, lower and lateral parts, the latter forming the bases of the palpi as well. The upper forward part of the mouth-ring, which is flattened and slopes downward and forward so as to closely invest the mandibles, is projected forward as a mandibular sheath (Fig. 6, *ms*), splitting in the middle and rounded at the sides so as to form two imperfect chitinous tubes at the anterior border of the ring continuous with two membranous tube sheaths running posteriad to about the posterior border of the ring. The forward parts are gradually constricted until, instead of being doubled into three-quarter cylinders around the mandibles, they are folded above them (Fig. 7, *ms*) so that the lateral edges are underneath the median, the two edges being connected by membranes throughout. The entire surfaces except the membranes are covered with minute denticles, about 4μ long, from near the anterior border of the mouth-ring to the outer end. This denticulated surface is about three-fourths of the outer surface of the proboscis, as it comes down to the edge of the hypostome on each side, and is continuous above. The sheaths are connected into complete tubes by membranes between the margins. In the outer part this membranous connection is rather indefinitely folded; this is not shown in the drawing.

The lower part of the ring is projected forward as the hypostome (Figs. 8, 9, 10) something over 325μ in length. It is split in the median line, as is the sheath, but not plainly so and its edges are not doubled over in the same way. In fact the two parts are so closely joined as to ordinarily appear as one piece. In addition to a slight spoon-like hollowing of the dorsal surface of the hypostome is a little triangular groove running down the dorsal median line from the base and gradually narrowing to a point at the tip. This, together with the triangular space formed by the curved surfaces of the closely apposed mandible shafts forms a canal continuous with the opening of the pharynx on the anterior ventral floor of the buccal cavity. This canal is about 30μ in diameter at the base (Figs. 11, 12, 13, *g*). The ventral surface of the hypostome, at 30μ from the mouth-ring, is provided with rather small retrorse hooks, gradually increasing in size until a maximum length of about 30μ is reached at about 40μ from the distal end. At this point the hypostome has a thickness of some 90μ, 24μ of which is taken up by the slanted hooks (Figs. 8 and 10). At the outer extremity the hooks dwindle in size until their character is only recognizable in sections. The hypostome has a maximum width of about 180μ rounding at the outer end and tapering slightly posteriad from a point about one-third the distance from the distal end (Fig. 11). The hypostome and the mandibular sheaths are about the same breadth and there is enough turn to the margins of both structures, so that they may be closely pressed together into a tube, thickly covered in its entire circumference by retrorse hooks (Fig. 9). The sheath hooks, though small, are very powerful by reason of their immense numbers, and they leave their marks in the piece of skin torn away from the cow almost as plainly as the much larger hypostome hooks. The chief function of these combined sets of hooks is undoubtedly that of permanent holdfast. The parts do not normally form a complete tube but are slightly separated. In pushing into the hole cut by the mandibles they are much compressed so that the elasticity of the chitin is sufficient to keep them fast, without any muscular effort. They are surely very important also in penetrating the skin of the host, as they must, after a start is obtained, hold securely enough to give valuable leverage for the mandibles to be pushed farther in.

In form, the mouth-ring, the base of the palpi, mandibular sheaths and hypostome, taken together, might be likened to a funnel, the stem formed by the two latter parts while the bowl is formed by the hollowed posterior aspect of the ring, with a very short heavy inner tube occupying about the upper two-thirds of the cavity of the bowl. This tube closely invests the mandibles, acting as a stay and guide for them. (Fig. 9 gives a fair idea of the relation of these parts from side view.) It is readily seen here that the lower part of this inner tube is formed by the posterior projection of the upper part of the hypostome forming a sort of little platform. This little platform is perforated with a large opening to admit the pharynx from below (Fig. 10), and a part of this opening is covered over with a membrane which forms the floor of the mouth cavity (Fig. 11, triangular shaded area).

The anterior external dorsal surface of the mouth-ring has two roughened areas which are sense organs of some sort. They are almost rectangular in shape, about 240μ by 90μ, occupying together about one-half the anterior dorsal aspect of the ring. The rough spots seen in external view are shown by sectioning to be the openings of minute canals through the chitin, widened at the inner end and connected to a nerve fiber. Presumably their function is olfactory (Fig. 14, *of*). Starting from near the external opening of each canal, a thin-walled tube, indistinct at the outer part, runs inward with uniform diameter, thus appearing in the middle of the wider part of the canal as though suspended from the narrower (Fig. 15, *it*). About two-thirds the length of the canal from the outer end this tube stops abruptly, giving off four or five little branches which look somewhat like little rootlets. These are very small and short, and being rather dark in the sections, look simply like tiny granules. In one specimen, one of these tubes had been broken and turned at an angle of about 45° at the wide end of the canal. Occasionally nuclei are seen in the wide inner ends of the canals (Fig. 15, *n*). From a direct posterior view the mouth-ring looks like an ellipse divided into three parts, the two ends and a middle part comprising about half the total area. This appearance is due to the showing made by the bases of the palpi, which are almost like quarter spheres in form. Their hollows form part of the cup of the mouth-ring.

The palpi are set on the inner three-fourths of these bases, the inner face, smooth and straight, being continuous anteriorly with that part of the base which forms, with the hypostome, the inner ring or tube. They are well supplied with muscles and tracheae; their nerves have not been traced. Their chitinous walls are of very irregular thickness and are not quite so hard as in the other appendages. In fact it seems to be only slightly harder than that of the main body surface. The thickness is greater at the various angular projections and between joints, than at the joints, although the latter do not seem to have very much mobility. The mean thickness of the walls is not far from 25μ. The fourth, or distal segment, is a small, rounded, peg-like protuberance, bearing four to six terminal hairs which are rather small. Its walls are thinner and apparently softer than in other segments and the hairs are set directly in through the thin terminal chitin, thus differing from the numerous hairs on the other segments which are set in sockets as on other parts of the body. This segment is about 45μ long by 33μ wide and is very loosely articulated, sometimes pointed toward the median line of the proboscis (Fig. 16), sometimes at a considerable angle from this direction, but its situation on the inner terminal surface of the third segment keeps it always pointing somewhat to the median line. It is probably tactile in function. In the free tick the palpi stand close against the mandibles and hypostome on each side, but when the proboscis is inserted into the skin of the host they are spread far out, even at a right angle.

The male mouth parts are quiet similar to those of the female in the details of structure; the main difference being their greater delicacy and weakness. The differences in the larva have already been noted. The walls of the palpi are thinner, however, and its three segments are much smoother, the very large second segment, bearing the papillary segment about the middle of its distal end.

The mandibles are irregularly cylindrical organs, nearly 800μ long, and readily divisible into three regions: a basal region about 14μ broader than the rest; a fairly uniform shaft region; and the terminal apophyses (imperfectly indicated in Fig. 9). The basal region is about 300μ in length, extending from the rounded and notched posterior end of the organ to the abruptly narrowed shaft region. It is the region of attachment of the muscles of the apophyses, which give a bi-pinnatifid appearance to its entire internal structure in longitudinal section. Beside the abrupt narrowing the main shaft is further distinguished from the basal part by an area of thin transparent membrane about 130μ long, and extending across the dorsal surface laterally to the ventral surface, thus comprising very nearly the outer half of that part of the shaft surface. The shaft part comprises a length of nearly 400μ. The bi-pinnatifid muscle structure is continued some distance from the basal part but gradually the tendons become more prominent near their insertion into the apophyses. The only other structures shown in the mandibles are two air-tube branches (Fig. 12, *at*) to each mandible, both entering at the proximal end and traversing the entire length of the organs. One is near the median, the other near the lateral border. The apophyses are articulated with a sort of combination hinge and socket joint. The socket is very shallow, however, and as motion is limited to one plane the hinge feature is much the more prominent. The base of each apophysis is enlarged into a sort of rocker with muscles attached to heel and toe of the rocker, the one set throwing the points out and down, the other raising and straightening them. I agree with Dr. Salmon who states that the internal apophysis is bidentate instead of conical, as described by Neumann.

All the muscles which work the mandibles as a whole are attached at the proximal end. The retractor muscles run from that point to near the fourth pair of legs. The extensor muscles have not been traced. The basal enlargement of the mandibles would seem to be useful in two ways; first, by giving more room for the insertion of the muscles they contain; second, to wedge into the anterior mouth-ring so as to prevent being pulled out. The thin membrane at that point doubtless reduces friction and makes possible a better fitting of the parts.

Digestive System

The alimentary tract, while not very complex in structure, is so folded and twisted as to give a very complicated appearance. Beginning with the opening of the mouth it goes almost directly backward for a considerable distance, then turns somewhat sharply and running diagonally toward the anterior ventral part of the body, and curving somewhat abruptly backward and upward to pass through the brain in about the median line. In some specimens this course is much less tortuous. Thence it extends posteriad a short distance, giving off at right angles, opposite right and left branches (Fig. 17). Almost immediately behind this point the main line runs diagonally ventrad to the cloaca, a single branch continuing in about the former median line. This continuation is, however, very short, ending in four branches like the tines of a fork (Fig. 17, *pd*). These four branches are quite long and usually run toward the posterior dorsal margin of the body, turinng downward, then forward, at the end. From near the origin of the two lateral branches first given off, are derived at intervals four other branches, making a total of five diverticula to each side (Fig. 17, *ld*). The main lateral branches run backward along the lateral body wall to the stigmates, there turning downward and forward. The secondary lateral branches run to the lateral or antero-lateral walls and then turn downward and inward to become almost inextricably tangled together.

It may be readily seen that the alimentary tract can be conveniently divided into six regions, the buccal cavity, pharynx, oesophagus, lateral diverticula, posterior diverticula, and intestine.

The buccal cavity is mainly a shallow, sub-triangular space between the platform made by the posterior projection of the hypostome and the mandibles (Fig. 9). The apex of the triangle is at the point of fusion of the mouth-ring with the proboscis and it is only the width of the median groove of the hypostome at that point, or about 30μ. At the base of the triangle, formed by the posterior border of the platform, it is about 150μ in width; the normal depth is about 10μ. The pharynx opens from below in the median line and anterior half of the cavity. It is only a slit with lips usually close together but opened slightly at the anterior end. At each corner of the base of the triangle are the openings of the salivary ducts (Fig. 11), each about 30μ in diameter. Hence there seems to be an irreconcilable conflict as to right of way of outgoing saliva and incoming blood. After careful study of over fifty specimens, dissected or sectioned in various ways, I have only this explanation to offer. When boring through the skin or at other times when the animal is not sucking blood, the saliva may flow freely over the floor of the buccal cavity and down the canal between mandibles and hypostome; but when this is occupied by incoming blood the lips of the pharyngeal opening and the nearby floor will have been raised somewhat by the suction and blood stream so that the way to the canal is blocked. As at this time the mandibles are somewhat relaxed and retracted, it is probable that there is room enough about the outer and upper surfaces of the mandibles for the saliva to escape. It is also possible that the currents may alternate, saliva flowing in intervals of rest from suction. It is evident that any apparatus set apart especially for conducting fluid from ducts of such size would be easily found.

The length of the pharynx varies somewhat but is usually between 400μ and 500μ. The width is still more variable, but averages in dorsal view 100μ (Figs. 11, 14, 18, *ph*). With the exception of the slight terminal bend dorsad of the opening in the floor of the buccal cavity, this portion of the canal extends almost directly posteriad from the middle of the mouth-ring; narrowing abruptly at the oesophagus. In dissected specimens it appears simply as a large strip of thin membrane with three or four longitudinal lines, due to doubling of the walls of the empty organ (Fig. 14, the folds appearing as cornua in cross section). In transverse sections it appears roughly as two thin crescents turned with convexities together. Strong muscles are inserted over almost the entire concave surfaces, their origin being in the mouth-ring or the lateral walls of the body. There are also four muscles with both attachments on the organ itself. One each connecting the dorsal and ventral horns and one to each side connecting the two horns on that side. These four muscles are small and scattering. The pharynx is constructed in two layers, the outer cellular layer about 3μ thick and composed of cells with nuclei so relatively prominent that they are almost the only evidence of such a tissue; and the inner chitinous layer, just a little thicker. The small sets of muscles acting on the horns of the crescents, together with the elasticity of the chitin and the pressure of surrounding parts, tend to constrict the tube. On the other hand, the large muscles tend to open it and so create the suction which draws blood from the host.

The oesophagus is of pretty uniform size throughout. It is much the narrowest part of the whole digestive tract, ranging from about 60μ in most parts to about 30μ in the brain. The lumen is almost entirely closed by the constricted walls in all my sections. The structure of the walls is not clear. Some sections indicate three layers: An outer layer of thin cells much thickened at the comparatively large nuclei but with cell boundaries not distinguishable. A middle layer of either connective tissue membrane or, possibly, circular muscles, these two layers together being only from 3μ to 6μ thick. An inner layer, very thick compared to the others, being 15μ to 30μ, and consisting of columnar cells of varying lengths; in the brain these cells are cuboidal (Fig. 19). The nuclei in both inner and outer layer are round and about 6μ in diameter. In the inner layer they may be seen in various parts of the cells. Some sections indicate only two layers corresponding to the middle and inner layers above, the delicate outer layer probably having been destroyed in the preparation of the sections. The oesophagus begins to widen gradually as it nears the posterior border of the brain and the character of the walls of the canal is changed sufficiently just beyond the posterior border to indicate that as the hindmost extremity of the oesophagus (Fig. 19). It should also be noted that the oesophagus, together with two or three nerves, is enclosed within a thin membranous tube much more than twice its size, which is continuous with one of the membranes surrounding the brain (Fig. 19).

Under the name intestine will be considered that part of the alimentary tract running directly from oesophagus to cloaca. It is approximately 200μ in length and varies very decidedly in width according to degree of engorgement. In the widest part most measurements would fall between the extremes of 200μ and 800μ. Only a little wider than the oesophagus at the anterior end, it widens rather rapidly, then runs fairly uniform for some little distance, tapering gradually in the last 800μ, to its junction with the cloaca, where its diameter is quite small, only about 60μ. Its wall is composed of two layers throughout, an outer very thin layer, 5μ thick, as a sort of basement layer, and an inner columnar cell layer (Fig. 20). The individual cells would seem to be somewhat amoeboid as they appear in many different shapes, the most characteristic being the club shape of the larger cells in the drawing. This layer is a little more than 30μ in thickness, varying, of course, as the individual cells are extended or contracted. The cells vary in width from 8μ to 15μ. Both cells and nuclei stain deeply, but the nuclei are considerably more dense and more coarsely granular. Most nuclei are round, nearly the same diameter as the width of the cell. They vary in position anywhere from the base to the tip of the cell but they are usually near the outer end of a club-shaped cell. The cloaca in an unfed specimen is a short tube with a very small opening through the valves of the anal ring. In the only cross section showing to good advantage, the anal area has the following structure: A heavy ring of hard chitin with thickness about 25μ, dished on inner dorsal face and surrounding very closely a bowl-shaped chitinous plate, with convexity facing out (Fig. 21), looking as though a bowl had simply been set into a rack made to exactly fit it. The mean thickness of this bowl is about 10μ. It has a little antero-posterior slit in its middle, 6μ wide, filled up with folds of thin membrane. In engorged specimens the cloaca is swollen to enormous proportions and is globular in form, often being 1 mm. or more in diameter. This distension is due to its becoming filled with excretory material from the Malpighian tubules, which enter near its base, one at each side of the anterior face. The opening of the intestine is between and a little above those of the tubules. No evidence of any material from the intestine itself is ever found there, nor is there any evidence of any sort of contents being voided from the anal cleft.

The digestive caeca are, as has already been noted, in three sets, two lateral, in the same anterior region, and one posterior. The lateral diverticula are essentially similar, so the left only will be described. At a short distance behind the junction of the intestine with the oesophagus, a branch turns abruptly to the left. At a distance of some 400μ from the intestine it gives off the first secondary branch, the other three being given off rapidly from outside of it (Fig. 17). The first is the shortest, the other three being nearly alike in length, as all are in diameter. Of course, size varies greatly with engorgement. The drawing was made from an engorged specimen in which the left secondary branches measured in order from the intestine; 4 mm., 4.5 mm., 5 mm., and 4.5 mm., a total of 18 mm. On the right the measurements were 3.5 mm., 5 mm., 5.5 mm., and 5 mm., a total of 19 mm. These secondary branches run to the lateral and anterior walls of the anterior half of the body turning down to the ventral wall and along it toward the median line, becoming more and more twisted and tangled as they fill with blood. By the time these branches are given off, the primary branch has reached the lateral wall, which it follows backward past the stigmate, turning downward there and looping around the tuft of air tubes from the stigmate, thence proceeding forward along the ventral wall to mix with the ends of the secondary branches. Both right and left primary branches were 15 mm. in length in the specimen measured. The posterior diverticula arise from the end of a very short branch of the intestine which continues in the dorsal median line a little way beyond the lateral branches. They all arise from the end of this tube and so give somewhat the appearance of a four-tined fork, each diverticulum representing a tine. They spread slightly but all run backward near the dorsal wall, turn downward at the posterior body wall and run forward ventrally, sometimes turning up and back again as they are crowded by the forward tubes in engorgement. These tubes are each about 13 mm. in length. The combined total length of all diverticula is approximately 60 mm., and since all are about 1 mm. in width in an engorged specimen, it is easily seen that they store up an enormous amount of blood for use in the production of eggs. The structure of the walls of the diverticula is essentially that described for the intestine except that the cells and nuclei range higher in size. To the naked eye the engorged diverticula look like long slender sacs of thin shiny membrane, dark purple or almost black on account of the blood they contain. They exert considerable pressure against the skin and are partly extruded if even a small hole be cut through the integument. When the entire dorsal skin is removed they appear as a confused dark mass varied here and there by the white Malpighian tubules or the delicate air-tubes. In the rabbit tick, *Haemaphysalis leporis-palustris,* a very active peristalsis was observed at the proximal parts of the diverticula which seemed to drive the blood continuously to the blind end of the sac. This rabbit tick is very strikingly similar to the cattle tick in internal structure, even to the number of diverticula, and it is almost certain that this movement must also occur in the cattle tick. Of course, this movement must be of considerable importance in drawing the blood away from the oesophagus and pharynx and in keeping it in the sacs. If there are valves in the diverticula, they have not been demonstrated.

Blood is almost the only material within the alimentary tract. In most specimens it is in a sort of semi-coagulated condition, making a kind of stringy, fluid jelly, but one or two engorged specimens were dissected in which the contents were almost watery in their fluidity. Smear mounts made of these and stained with Wright's Romanowsky methylen blue stain showed a few multinuclear amoeboid cells. Some of the same material mounted in water and stained with ordinary methylen blue showed these same structures in amoeboid movement; their size varied from 21μ to 25μ. Other amoeboid structures were also observed. Attempts to examine the contents of ordinary specimens were not successful.

The alimentary tract of the male is quite similar in general form to that already described but nothing further has been determined. Not even so much has been worked out for the larva.

SALIVARY GLANDS

The salivary glands consist of a single pair of compound alveolar glands resembling in gross appearance a somewhat elongated cluster of grapes (Fig. 6). They are something over 2 mm. in length, over all, and in the unfed tick occupy a large proportion of the inside of the body, extending from the opening of the ducts in the buccal cavity posteriad along each lateral wall to the stigmates. In this condition they are not extended to their full length. But as engorgement proceeds they occupy a very much smaller relative area since their dimensions remain fairly constant. By this displacement in engorgement they finally come to occupy a somewhat diagonal position from mouth-ring to lateral wall, keeping rather near the body wall throughout. The tips of the glands in such case lie near the lateral wall in the region of the second pair of legs. The globular alveoli vary considerably in size, ranging from 45μ to 90μ in diameter; the cavity of the alveolus is also somewhat variable, sections indicating it to range from one-sixth to two-thirds the total diameter of the alveolus. The cavity is connected with the branch duct by a little canal surrounded by from three to six basal cells with their outer parts extended to connect with the wall of the duct (Fig. 22); this extension makes them slightly pyriform. These basal cells have nuclei in their broader part which are excessively stained; most of these nuclei are oval, about 6μ by 9μ, but some are round, 9μ in diameter. The heavy stain makes them appear perfectly homogeneous. The cytoplasm stains very lightly and is distinctly reticulated. The typical alveolar cells are nearly cubical and about 24μ in diameter; they have nuclei of about the same size as the other, but more often round and never so heavily stained. They contain a large number of granules, rather fine, and some of them show a distinct nucleolus about 1 μ in diameter. The cytoplasm is the same as in the basal cells. In many cells, though usually not more than three or four in the alveolus, are seen very large nuclei, round or slightly oval, about 21μ in diameter and intensely stained. They are distinctly granular, with the granules rather closely set together. In such alveoli, the smaller nuclei are crowded to the wall or are not seen at all, but the cell boundaries are so indistinct as to make it difficult to say that the large and small nuclei occur in the same cell, although it looks that way. In some alveoli the entire globule is occupied by these structures, so much so that the alveolar structure is difficult to see at all. Many of these large nuclei also seem to have a layer of some kind of granular substance slightly denser than the cytoplasm, surrounding them. The real character of these apparently abnormal features is not clear. Borax-carmine is a good stain for them.

The gland ducts run as directly as possible from the glands to their openings into the buccal cavity. They penetrate the chitin platform forming the floor of that cavity at the posterior border. The main ducts have a lumen nearly 30μ in diameter; the smaller run as low as 15μ. The walls are in two layers throughout with a nearly uniform thickness of 10μ. The inner layer of chitin is very thin and it is so arranged as to give a spiral marking to the inner wall of the tube; it is about 2μ in thickness. The outer cellular layer is composed of flat cells with oval nuclei; the cell boundaries are not distinct. The nuclei are 9μ by 6μ; they appear to be finely granular. The cytoplasm has no distinctive structure. Salivary ducts and air-tubes are so essentially alike in structure as to be indistinguishable except by location and tracing. In the male the salivary glands are rather smaller in porportion to the size of the animal and hence actually considerably smaller. Otherwise their appearance is the same. The embryonic glands have not been studied.

Malpighian Tubules

These are white tubules, not very prominent in the unfed tick, but very strikingly so in the engorged specimen. In the latter they are easily recognizable through the skin, appearing as dirty white lines marking the body and sometimes showing pulsations. Their course is very irregular; no two ticks show exactly the same markings and variations occur in the same individual from time to time. Whether the pulsations are due to the contractions of the tube itself or to the movements of the body muscles is not known. The tubules are two in number, very long and delicate (Fig. 23, one shown entire and the other in part). They open into the cloaca, as has already been noted, on the anterior side near the external opening. Thence their course is so tortuous and they are so badly mixed and tangled up with air-tubes, muscles and other organs that it is practically impossible to get the two out entire. In fact, out of thirty or forty dissections made for this one purpose, only two were successful in getting out even one tubule intact. Specimens about half engorged were most favorable for this dissection. In a female 5 mm. long the tubules were each about 20 mm. long. In a fully engorged female, 13 mm. long, they were 74 mm. in length. As a general thing each tubule is at least four times the length of the body. The width is extremely variable in different parts of the same tubule, *e. g.*, it may be only about 50μ in width at one point and nearly 500μ in width within 2 mm. of it. In fact, one of the greatest troubles in dissecting is with these narrow, empty parts, where the tubule is almost invisible as it is practically colorless and is particularly hard to see amongst the air-tubes and other structures. The trend of the tubules from the cloaca is backward by a tortuous course to the posterior body wall, thence upward and forward in the same sinuous way to the junction of the lateral diverticula with the intestine, where they are attached to the diverticula at a short distance from the intestine. While no open communication is demonstrable between the two kinds of tubules at this point, their connection is so very close that the Malpighian tubule will invariably break elsewhere without losing the contact. This connection occurs at just about the middle of the Malpighian tubule. The significance of the connection is not known. (Fig. 23 shows a piece of the intestine, *lit,* attached.) From this point the tubule trends backward to the sigmate, turning down usually through the midst of the mass of air-tubes to the ventral wall and thence going forward to end as a blind sac somewhere near the anterior body wall. This description of its course gives absolutely no idea of the tangle through which one of these tubules must be traced, a tangle due in great measure to its own twisting and turning and doubling.

The wall of the tubules is composed of a single layer of cells varying from columnar in an empty part to flat in a distended part (Figs. 24, 25). Those of the cuboidal form have a diameter of 24μ in cross sections. The cytoplasm stains quite strongly with haemalum and shows a finely granular structure. The nuclei are mostly round, 15μ in diameter, but some are oval and so large as 15μ by 21μ. They are coarsely granular and nearly all show at least one nucleolus, some three or four. The contents of the tubules is white; a rather thick, sticky fluid, very difficult to cleanse from dissecting tools. Under the microscope it appears to be entirely made up of little black disks or globules which are not very uniform in size though most of them appear to be about 10μ. Other sizes are well represented from 15μ down to 2μ in diameter. No study has been made of the male and embryonic tubules, except enough to show that the male is very much the same in every way.

RESPIRATORY SYSTEM

This is a double system of very complexly branched air-tubes with the two parts more or less connected with each other, especially near the median plane of the body. The external openings are marked by two discoidal chitinous plates, one just behind each of the last pair of legs. Just inside these plates are shallow cavities or atria into which the air passes through the external opening. From each atrium a number of large tubes branch; the number is not exactly determined but there appear to be not far from fifteen. The difficulty in counting lies mainly in the fact that some of these tubes branch very close to their origin. The tubes extend in every direction, some up the side wall, some back, some to dorsal and some to ventral walls, others out into the body cavity; and all give off numerous branches. From larger branches, smaller arise until every part of the body is supplied with minute air-tubes, the air being thus brought directly to the tissues instead of through an intermediary fluid or blood. Those branches from each side which meet in the median plane very frequently coalesce. This is true both of capillary tubes and of medium-sized branches. In this way a sufficient supply of air may be obtained for the whole body even though one external opening should be closed (Fig. 26, showing the fusion of tubes from each side at the brain). The stigmal plate is about 40μ in thickness. Its structure resembles in appearance somewhat cancellated bone. It has hard outer and inner surfaces, each about 10μ thick, and a median part appearing somewhat like an open space traversed by numerous small and closely set pillars connecting the two surfaces (Fig. 27). The stigmate is somewhat over 300μ in diameter. Near its middle and set diagonally to the dorso-ventral line is an irregularly elliptical, crater-like opening of very irregular outline, 180μ by 135μ in greatest dimensions. The opening narrows very abruptly to the atrial entrance. The posterior wall has a knob or tongue of heavy chitin projecting over the opening, and the effect of a valve seems to be produced by closely pressing the anterior wall against this. Not enough good sections are available, however, to make the mechanism perfectly clear. The atrium is 120μ in depth by 150μ in width. The principal trunks branching from it are about 50μ in diameter. The walls of the atrium are of the same structure as the walls of the tubes. These are in two layers, an inner chitinous and outer cellular; the former is very thin, not more than 2μ in the large tubes, while the latter at the same point is only 4μ in thickness by 15μ in breadth. The air-tubes, then are slightly thinner walled than the salivary duct, the difference being in the cellular layer. The cell substance is finely granular; the nuclei are oval, finely granular, deeply stained and 4μ by 9μ in dimensions. The air-tubes in the male are the same as in the female. Embryonic forms were not studied.

Nervous System

The nervous system consists of two distinct parts, a central ganglion or brain (Fig. 26) and the nerve trunks and fibers communicating with it. The brain is about 350μ from the anterior wall of the body in the engorged tick, and between the planes of the mouth parts. It is an irregularly oval mass, with the smaller part dorsad and penetrated by the alimentary canal about three-fifths of the distance from the larger end (Fig. 9). It is not very securely held in place. In the freshly dissected specimen it is white and the white nerves running out from it give it somewhat the general appearance of a white mite. It is about 400μ long by 480μ wide and 320μ thick. It is well supplied with air-tubes. One specimen (Fig. 26) was dissected out which showed two air-tubes from opposite sides sending tiny branches over the ventral surface. The nerve trunks are in pairs, five larger and two smaller. One large pair arises from the anterior face of the brain and runs forward, each nerve branching very soon after leaving the origin. The four other large trunks are lateral and probably supply the legs, though only the anterior pair have been traced to the anterior legs. Of the two smaller pairs, one is anterior and the other posterior, one nerve from each lateral margin of these faces. There are also a few very small nerves direct from the brain. The larger trunks are 50μ in diameter, including the sheath, or 30μ alone. This difference is only appreciable in a section. The brain is fairly closely enveloped by a membrane which, however, extends out loosely around the nerve trunks, enveloping them as far as traced. It is also extended as such an envelope about the oesophagus, including perhaps, as some sections indicate, some very small nerve branches. In structure, the brain follows the usual invertebrate type in having cells outside and fibers in the middle. Cell outlines were not shown, however (Fig. 9). Fibers are indistinguishable except as a tangled mass. The round nuclei are strongly stained, finely granular, with rather distinct nuclear membrane. They are about 6μ in diameter. The membrane surrounding the brain is 4μ to 5μ thick, and while cell boundaries are not evident, it has numerous oval nuclei, 4μ by 6μ, staining strongly and somewhat granular. The nerve trunks are made up of extremely small fibers with a considerable number of scattered nuclei, ellipsoidal, 12μ by 6μ, although not constant in either shape or size. They stain very lightly, are finely granular and have a distinct nuclear membrane.

Reproductive System

The external genitalia of the female are not usually very prominent. Ordinarily there is simply an oval transverse ventral orifice in the region of the second pair of legs and on the median line; or on the anterior ventral margin in the engorged specimen. But in egg laying, the ovipositor may often be seen as an external organ, though only temporarily so. This organ is shaped like a cow's horn with the concave dorsal line next to the mouth parts. Exact measurements are not available, but it is about 900μ in length and it stretches just wide enough for an egg to pass (400μ). When retracted the ovipositor appears merely as a vaginal tube, branching at the inner end into three tubes, a dorsal tube to the seminal receptacle and the two ventral tubes (right and left oviducts) which connect with the ovary (Figs. 28 and 29). On the dorsal surface, about three-fifths of the distance to the extremity are the openings of the two ducts of a pair of accessory, simple tubular glands. These ducts open near the lateral borders of the dorsal surface. The two-layered wall of the ovipositor-vagina is composed of a chitinous membrane, some 12μ thick as it appears in relaxed vaginal position; built upon a cell layer essentially the same as that of the general integument.

The seminal receptacle is a pyriform or gourd-shaped sac (Fig. 29), the stem extending almost directly posteriad from the end of the vagina-ovipositor, as a thick-walled tube, some 240μ in width and 650μ in length, to its expansion into a thinner-walled, rounded pouch about 520μ in diameter. The walls of this part are 42μ in thickness and are composed of columnar cells from 15μ to 21μ in width. The cytoplasm is slightly reticulated but is mainly finely granular and stains but lightly. The nuclei are large and prominent, oval usually, 18μ by 15μ (Fig. 30). These nuclei stain rather heavily and have fine granules with a considerable number of coarser. The walls of the tube are about 60μ thick, composed of columnar cells 9μ wide with nuclei oval, 7μ by 9μ, more coarsely granular than those of the pouch walls, staining much the same and with cytoplasm similar. No spermatozoa have been found in this organ in any of the engorged ticks examined; and in most of those unfed, by far the larger mass of spermatozoa is found in the vagina-ovipositor and the ends of the oviducts; but a few specimens were found with sperm in this organ, and a larger or smaller mass of structureless material is seen in it in even engorged specimens. Although the indications are not very strong that this is a functional seminal receptacle, the location and structure certainly indicate that it is. The spermatozoa (Fig. 31) are 9μ to 15μ long by 2μ in greatest width, tapering uniformly from the rounded head to the finely pointed tail.

The two oviducts take rise from the ventral part of the extremity of the vagina-ovipositor and are almost immediately thrown into coils and loops forming a considerable mass at each side; after traversing this mass they immediately unite with the ovary, a long tube continuous with and connecting the two oviducts. In a fairly representative, engorged specimen each oviduct was 17 mm. in length by one-third of a millimeter wide. They are rather thin-walled elastic tubes. In the egg-laying specimen the walls are only 9μ thick or even less, the cells being 30μ or more in length. The nuclei in this case are extremely prominent, as many of them are 15μ or more in diameter; the larger nuclei are usually round, but the more common size and shape is 9μ by 12μ oval. The cytoplasm stains slightly and is somewhat reticulated, while the nuclei stain heavily and contain numerous fine granules with scattering granules of larger size. The tube of the ovary appears as a continuation of the oviducts from one to the other (Fig. 28). It runs from about the region of the second pair of legs backward just outside the lateral row of dorso-ventral muscles to the posterior wall, where it doubles forward inside the muscle row and loops around in front of the cloaca, going back inside the other dorso-ventral lateral row and forward again outside it. Its total length in the typical engorged specimen mentioned was 26 mm., its average width about 1 mm.

Its walls are highly modified in that they are covered with globular flask-like sacs with walls of extreme thinness. These sacs are all very small in the unfed female as they contain immature eggs, but as the eggs mature the sacs are enormously distended until the egg is fully developed, when it is discharged into the median tube. The variation in size then is from about 30μ to 400μ. While in these sacs the eggs are round. Sections show the sacs to be attached to the wall by means of a slight protuberance composed of apparently four to six cells in the smaller stages and a larger number in the later stages. These are doubtless nurse cells. Only two are seen in sections, and in a longitudinal section of the organ they have rather a trapezoid outline (Figs. 32, 33). In the case of an egg 60μ in diameter, these cells are 15μ in height by 18μ in breadth. Their cytoplasm is granular, lightly staining and slightly vacuolated. The nuclei stain deeply, have granules of medium size and are about 9μ by 12μ in size, though varying slightly; their shape is elliptical. The walls of the sac are too thin to measure, certainly not more than 0.5μ; their origin is not known. The mature egg escapes into the central tube of the ovary through the center of the group of nurse cells. The walls of the tube between egg sacs are the same as the walls of the oviduct. Eggs are developed very closely together, the nearest noted being 30μ apart. Of course, the fact that they develop scatteringly keeps them from dangerous overcrowding on the outside. Such overcrowding does occur in the tube, however, and I have dissected a very considerable number of ticks that had not laid eggs because the oviducts had become clogged. In apparently normal specimens, eggs are found two and three abreast even in the ovarian tube. When it is considered that neither this tube nor the oviducts is wide enough to pass even one egg without distension, the seriousness of the condition is readily seen. In the abnormal specimens referred to, masses of eggs were found both in oviducts and ovarian tube with four or five eggs abreast and entirely shapeless from the great pressure. Possibly this condition is due to the attempt of the animal to restrain egg laying in captivity.

Eggs in the oviducts are seen to have a thin chitinous shell; in fact, they show it in the ovarian tube though the chitinous character is not so evident. It is about 3μ in thickness. It appears to be formed in the egg sacs. An egg cell 60μ in diameter had cytoplasm rather well stained, showing fine granules and some vacuolation;

reticulation was also observable. The round nucleus was 30μ in diameter, finely granular, reticulated and slightly vacuolated; the nucleoplasm looked much the same as the cytoplasm even to depth of staining, the granules being a trifle coarser. There was a very large round nucleolus, 9μ in diameter and densely stained; it was excentric. The nuclear membrane was very distinct.

There are two kinds of accessory sex glands, the pair of simple tubular glands already referred to as entering the vagina-ovipositor, and a set of four tufts of compound tubular glands emptying by two large ducts into the shell-gland sac beneath the head-shield. The individual tubules of both kinds are strikingly similar in general appearance but there are some important differences of detail, mainly in the way of dimensions. The vaginal glands (Fig. 28) in an engorged specimen are 2.5 mm. in length including the ducts which are nearly 0.5 mm. The glands are about 240μ in breadth and the ducts nearly 100μ in breadth. The glands lie dorsally posteriad from the seminal receptacle. There is a distinct structureless membrane surrounding the gland, about 1μ in thickness, so that the gland walls may be said to be in two layers, the other layer being the large wedge-shaped gland cells (Fig. 34). The lumen of the gland tube is very small, varying somewhat around 18μ; even then most sections show it as not very clearly marked off and with lines or membranes intersecting it. The cells are something over 200μ in length from lumen to outer surface, a fairly representative specimen being 235μ. Cell boundaries are not very clearly marked and their width varies considerably, from 24μ to 36μ at the outer ends. The cell contents are conspicuously granular with comparatively small granules. Numerous vacuoles are present and are very irregularly distributed though many are near the lumen; they vary in size from 6μ to 30μ. All sections show vacuoles around or partly around most of the nuclei. The cytoplasm stains lightly. The nuclei are usually large and of various shapes, but mostly oval. They range in size from 15μ in diameter to 21μ by 36μ, more of them being of the larger size. They are very deeply stained and the nuclear membrane is not prominent. The nuclear contents are rather coarsely granular. In some cases a rather large nucleolus, 6μ in diameter, can be seen. The position in the cell is variable. Some sections show some very small nuclei, usually four or five, near the lumen of the tube, sometimes farther out. Their relation is not known.

The shell gland is seen in dissections as a bunch of white tubules occupying almost all the immediate anterior border of the body in dorsal view. On being dissected out, they are seen to be in four bunches or tufts, each of the four tufts having a duct which unites with the other of the same side to form a larger one, thus making two ducts, right and left, emptying into a sort of pocket beneath the anterior half of the head-shield. This pocket is just large enough to hold an egg and it is provided with three membranous, semicircular, curtain-like lips which envelop the egg, when thrust in by the ovipositor. These lips are hung to the anterior border of the head-shield. Two are lateral and the median one overlaps them in the inner halves. The two main ducts enter this pouch together at the posterior middle part though they are large enough to occupy more than half its width (Fig. 35). These main ducts are short, about 300μ long. The branches to each tuft are even shorter in some cases but they are slightly more variable than the main ducts. All the ducts are thin-walled, collapsible affairs which are hard to measure accurately; their width is, however, very nearly 150μ for the larger main duct and 90μ for the branches. The walls are about 12μ thick, 3μ of an inner chitinous layer, and 9μ of a cellular layer. The cells stain very lightly. They are some 15μ wide with nuclei 9μ in diameter. The nuclei stain fairly well and are slightly granular. While most of the tubes in a tuft branch two or three times, there are some which are unbranched. In all cases the cell structure is the same. The tubes vary considerably in size, but most would fall between 90μ and 120μ in width. The width of the lumen is even more variable; 30μ represents a common diameter although there are some as low as 10μ and as high as 90μ. This latter, however, is only found near a branching point. Taking a typical tubule for description: There is a very thin enveloping membrane 1 μ thick, the main wall being made up of wedge-shaped cells, in cross section, columnar in longitudinal section (Figs. 36, 37). In cross section the cells are 30μ in length and 10μ wide at the outside. These cells are stained very lightly and they are filled with finely granular substance. The nuclei are stained deeply. They are finely granular and very variable as to position in the cell. They are also quite variable in size, the most common size being about 10μ in diameter.

STRUCTURES OF UNKNOWN NATURE

In some ticks a fine, filamentous, colorless network was found on dissection, enveloping a considerable part of the internal organs and situated between them and the integument. This was quite prominent in some cases, especially in a few ticks about half engorged. In most cases it was not distinguishable from the network of air-tubes except by the use of the compound microscope. When thus examined the structure distinguishes it from anything else in the body. In the fresh, unstained specimen no color appears and outlines of nuclei are brought out only by the variations in density. Balsam mounts stained with haemalum do not differentiate much more sharply, but the structure here described is evident (Fig. 38). Some filaments are made up of cells in single rows, the whole filament in all cases being enveloped by a continuous structureless layer of thin membrane, not more than one μ thick in any case. The main body of such a filament, which is usually short, consists of cylindrical cells 12μ long by 18μ wide or even twice that size. Filaments in single rows rarely have more than twenty cells, ten being the most usual number; the end cells are rounded and so give a rounded end to the filament. Most filaments are made up of a double row of cells, both rows generally complete but often incomplete in varying degrees. Some cases are seen in which a filament of a single row has only one or two cells of a second row at one or another point. There are also a considerable number of filaments consisting of three or four rows, still grouped so as to retain the filamentous form instead of being spread flat. The end of a filament with a double row looks somewhat like the end of a loop, as though the double row might have been formed by the doubling of a single row filament. There is no other indication of this being true nor do all filaments look that way. The cells are often almost filled by the nuclei which are generally about 12μ by 9μ, oval in form, lying crosswise of the filament. Many of the nuclei are round, possibly due to their being caught in end view. The cell substance is coarsely and loosely granular and it stains very heavily. The nuclei are rather coarsely and very densely granular and they stain deeply. The filaments branch very irregularly to form the network already mentioned and the branches usually possess a double row of cells. There is no apparent distinction as to main line and branch in either size, appearance or structure. The filaments may be found almost anywhere in the body amongst the organs and tissues and they are usually scattering. Some can almost always be found entangled with the air-tubes near the stigmates. As already stated, some filaments and cells are found which are considerably larger than others. The outer end of a branch from the network is frequently seen slightly enlarged, and some may be found which are twice the breadth of the filament with cells correspondingly larger which gives the structure a sort of flask shape. Finally, in addition to specimens which seem to indicate that a number of end cells with their nuclei are coalescing, a definitely outlined, much enlarged, pear-shaped or globular structure may be found attached to the ends of some filaments. In the fresh, unstained specimen, this structure has pretty much the same colorless, semi-gelatinous appearance as the filaments, except that within the mass is seen one or more comparatively large, faintly brownish nuclei. In sections these bodies are seen to consist of a thin enclosing membrane, the same as the filamentous membrane and continuous with it, and the semi-gelatinous material containing the enormous nuclei, one or more in number (Figs. 14, 38, 39). The typical section shows this material very lightly stained and rather loosely, though finely, reticulated, and finely granular. The nucleus is very heavily stained, coarsely and loosely granular, frequently with one to several nucleoli. The nuclear membrane is not very distinct and the nucleus is often partly surrounded by a vacuole. An extremely well defined vacuole (sometimes two or three) of great size is a prominent characteristic of these structures. In a fairly representative body with a single nucleus, subtriangular, the length is 135μ, width 30μ, vacuole 90μ by 24μ, nucleus nearly round and 45μ in diameter. Few of these bodies are visible in the unfed tick or the first stages of engorgement, but numbers of them are seen in sections of fully engorged forms; and in many specimens they are so densely crowded in the anterior end of the body as to be entirely misshapen and indistinguishable in detail from the general mass. Aside from the exceedingly large number in the anterior end of the tick, occupying any available space ahead of the second pair of legs, the only considerable number is in scattering groups of ten to thirty mixed up with the air-tubes near the stigmates. One or two isolated bodies may occur anywhere in any organ, *e. g.*, in sense organs, as in Fig. 14.

One tick had a very peculiar looking structure, somewhat spindleshaped, more drawn out toward one end than toward the other. A part of one end of a cross section is shown in Fig. 40; it is about 500μ in length and is situated just in front of the left foreleg, lying diagonally in the bend of the wall a little nearer the ventral than dorsal part. It has an oval cross section measuring about 240μ by 420μ at the largest point. The two ends could not be entirely traced out on account of poor sections. The space it occupies is usually filled by either a Malpighian tubule or a digestive diverticulum, most probably the latter. It has a structureless wall about 2μ in diameter. Its interior is mostly filled with an unstained mass of finely granular material, but there are a large number of spherical cells, pretty uniformly 15μ in diameter, filled with very lightly stained homogeneous substance and with excentric nuclei, 6μ in diameter and always intensely stained. The nuclear contents are coarsely granular. There are slight variations in size of nuclei and they vary a good deal in form although most approach the spherical shape except for rather rough outline.

Still another structure not at all understood is next to the extreme anterior wall of the body and immediately adjacent to the mouth parts on ventral and lateral aspects. It looks as though the epithelial layer of the integument had been thrown into folds which open toward the chitinous layer and appear to be made up of glandular cells. (Fig. 41 is a representation of the open part of one of these folds.) The open part is more or less marked by a network of fine fibers. The cells are very large and look somewhat like those of the intestinal wall. The folds extend back from the chitin a maximum distance of about 500μ. The individual cells vary in size and appearance from those almost exactly like the regular tegumentary cell to the elongated club-shaped cell of the other type. A typical cell of the latter sort is 21μ wide at the outer end, 15μ at the inner end and a little more than 60μ in length. The cell substance is finely granular in most cases though somewhat reticulated in others. It is pretty strongly stained, especially with eosin. The nucleus is an elongated ellipsoid in shape, 33μ by 12μ, coarsely and very loosely granular, the granules taking the haemalum stain very strongly. The nucleus lies lengthwise of the cell with few exceptions. The shorter cells have more rounded nuclei. Far the larger number of nuclei lie close to the base of the cells, though there are all possible variations of position. If these be glandular structures, as their structure would imply, their use, or their method of discharging secretion has not yet been demonstrated. I have sections of four or five specimens that show these things pretty well but all are in engorged ticks.

NOTE

Since this paper left the writer's hands for publication another paper on the same subject has been published by Mr. S. R. Williams. As the two papers are decidedly at variance on certain points it becomes necessary to call particular attention to the more important of these.

It should be noted that the descriptions given above were made only after repeated examinations and demonstrations. Wherever possible dissections were checked against thin sections and *vice versa,* and furthermore sections in the three planes were checked against each other. Except for some formaldehyde specimens collected late in 1904 and used only for check and for details of the mouth parts, the writer's specimens were all living and apparently normal up to the time work was begun on them. The specimens sectioned were always in the fixing solution within two hours after killing, and frequently within fifteen minutes. As noted under technique, the animal was frequently fixed by the killing.

The points at issue are as follows:

1. Williams (p. 316) gives, in my opinion, too great prominence to the holdfast function of the mandibles.
2. He refers (p. 316) to cracks or crevices in the integument which I believe rather in the nature of folds.
3. The cloaca is called the "renal sac" (p. 317).
4. The description of the Malpighian tubules (pp. 323–324) is erroneous together with the systemic drawings and diagrams referred to, particularly as concerns the female. The female Malpighian tubules are unquestionably two simple unbranched tubes as may be seen when they are isolated.
5. The oviducts are said (p. 328) to be short, whereas they are very long. Williams has mistaken them in part for shell glands as in Figs. 19 and 20 in Plate XX. The real shell glands are not described at all and a pair of single accessory glands of unknown function are confused with the oviducts.
6. The character of the structure called the uterus is in question.

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NOTE: This valuable paper gives a most complete and accurate bibliography of the subject, so that references need not be repeated here.

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EXPLANATION OF PLATES

ABBREVIATIONS

a	Fourth segment.
ag	Accessory gland and ducts.
ah	Auditory hair.
ao	Anal opening.
ar	Anal ring.
A st	Alveolar stem.
a t	Air-tubes.
ats	Part of atrial space.
a u	Auditory vesicle.
a v	Anal valve.
b	Third segment.
b m	Basement membrane.
B s	Brain sheath.
Bu	Body wall.
c	Cells.
cf	Cell layer.
Chl	Chitinous layer.
chm	Chitinous membrane.
cl	Cellular layer.
clo	Cloaca.
d	First segment.
dc	Digestive cells.
dors	Dorsal lobe of brain.
e	Egg.
es	Shell of egg in oviduct.
ext	External opening.
fl	Floor of mouth.
g	Hypostome groove.
h	Jointed hairs.
hk	Hooks.
hs	Head-shield.
hy	Hypostome.
i	Integument.
in	Intestine.
is	Insertion fibers.
it	Inner tube.
ld	Lateral diverticula.
lit	Lateral intestinal diverticula.
lmt	Left Malpighian tubule.
m	Mandibles.
mo	Mouth.
mh	Mandibular hooks.
mr	Mouth-ring.
ms	Mandibular sheath.
mus	Muscle.
n	Nucleus.
nc	Nurse cells.
nt	Nerve trunks.
o	Ovary.
oes	Oesophagus.
of	Olfactory organ.
olf	Olfactory organ.
op	Opening.
os	Open space.
ovd	Oviduct.
p	Palpi.
pd	Posterior diverticula.
ph	Pharnyx.
rmt	Right Malpighian tubule.
rs	Oesophagus.
sav	Salivary alveolus.
sd	Salivary duct.
sgs	Part of opening of shell gland.
sh	Shaft.
sp	Spaces.
SR	Seminal receptacle.
va	Vagina-ovipositor.
vent	Ventral part of brain.
vw	Vesicular wall.
wov	Wall of ovary.
x and *y*	Structures of unknown function.
Y^{K}	Yolk.

PLATE XXVIII

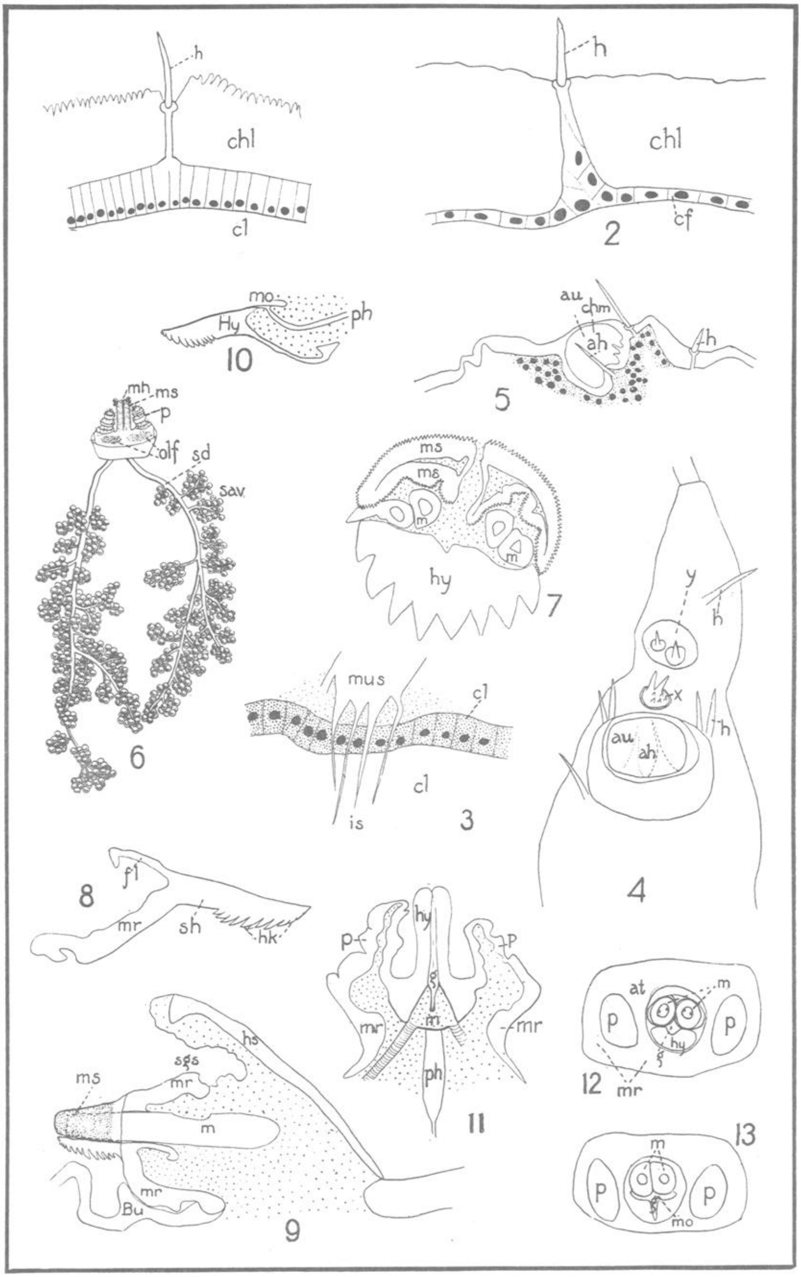
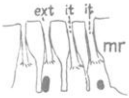


PLATE XXIX



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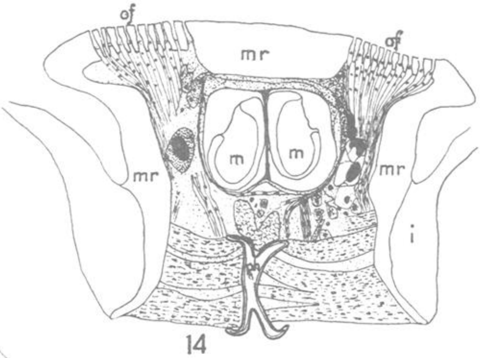

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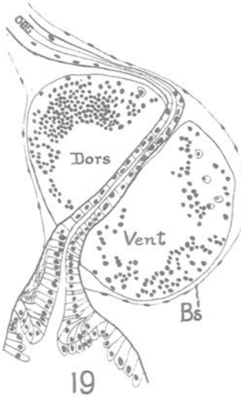

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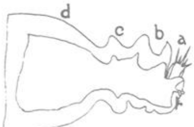

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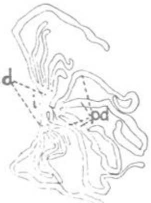

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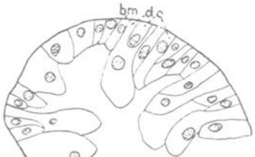

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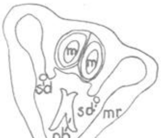

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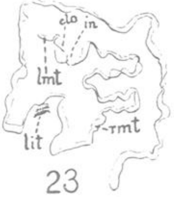

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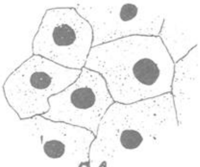

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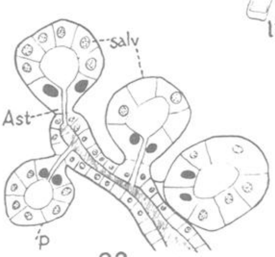

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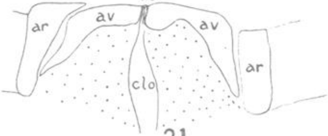

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EXPLANATION OF PLATES

PLATE XXVIII

Fig. 1. Section of integument in partly engorged specimen. Note toothed edge caused by section of skin folds. × 150.

Fig. 2. Section of integument in engorged specimen. Note nearly smooth outer surface and cells pushed up into hair channel. × 150.

Fig. 3. Section of body wall to show insertion of muscles. Note insertion fibers penetrating cell layer and ending in chitinous layer of integument. × 150.

Fig. 4. Surface view of auditory organ *in toto.* × 150.

Fig. 5. Longitudinal section of leg showing auditory organ. × 150.

Fig. 6. Salivary glands showing relation to mouth parts. Dorsal view. × 20.

Fig. 7. Cross section of proboscis not far from distal end. Note minute denticles of mandibular sheath and larger denticles of hypostome. × 35.

Fig. 8. Hypostome, etc. × 50.

Fig. 9. Longisection of mouth parts just at left margin of proboscis. × 35.

Fig. 10. Longitudinal section through mouth showing entrance of pharynx from below. × 20.

Fig. 11. Longisection of mouth parts in frontal plane at level of upper surface of hypostome. × 50.

Fig. 12. Cross section of proboscis just at junction with mouth-ring. × 35.

Fig. 13. Cross section of mouth-ring. × 35.

PLATE XXIX

Fig. 14. Cross section of mouth-ring. Slightly diagonal. × 80.

Fig. 15. Olfactory organ, cross section. × 215.

Fig. 16. Palpus, longitudinal section. × 50.

Fig. 17. Outline of intestine of partly engorged specimen 9 mm. long. × 3.

Fig. 18. Section mouth-ring near posterior margin. × 35.

Fig. 19. Longitudinal section of oesophagus in the brain. × 80.

Fig. 20. Part of cross section of intestine. × 80.

Fig. 21. Cross section of anal plate. × 150.

Fig. 22. Longitudinal section of a branch of the salivary duct with alveoli. × 135.

Fig. 23. One Malpighian tubule and part of another, from a specimen 9 mm. long. × 3.

Fig. 24. Surface view of cells forming the wall of a Malpighian tubule. × 130.

PLATE XXX

Fig. 25. Part of cross section of Malpighian tubule distended. × 150.

Fig. 26. Ventral view of brain showing two air-tubes and the main nerve trunks. × 15.

Fig. 27. Part of cross section of stigmate. × 150.

Fig. 28. Female reproductive system. × 5.

Fig. 29. Longitudinal section of seminal receptacle. × 35.

PLATE XXXI

Fig. 30. Wall of seminal receptacle. × 150.

Fig. 31. Spermatozoa. × 215.

Fig. 32. Four immature eggs; one with nucleus. × 130.

Fig. 33. Egg, nearly matured, still in sac. × 130.

Fig. 34. Accessory sex gland, cross section. Note small lumen marked by loose network. Also note indistinct irregular vacuolation of cells. × 130.

Fig. 35. Shell gland spread to show the four tufts and their ducts. The two main ducts empty into the shell-gland sac, only part of which is shown. × 15.

Fig. 36. Cross section of shell-gland tubule. Note slight vacuolation of cells near lumen. × 130.

Fig. 37. Longitudinal section of shell-gland tubule. × 150.

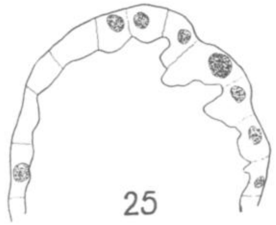
Fig. 38. Unidentified structures. Filaments and large bodies probably derived from them. × 150.

Fig. 39. Unidentified structures. Groups of large cells derived from filaments. × 150.

Fig. 40. Unidentified vesicle found in one specimen. Part of one end of section. × 150.

Fig. 41. Part of unidentified structure around mouth parts at inside of anterior body wall. × 150.

PLATE XXX



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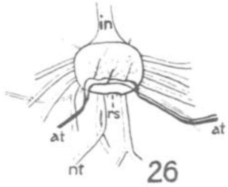

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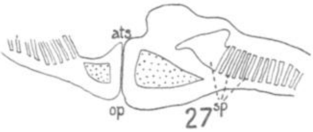

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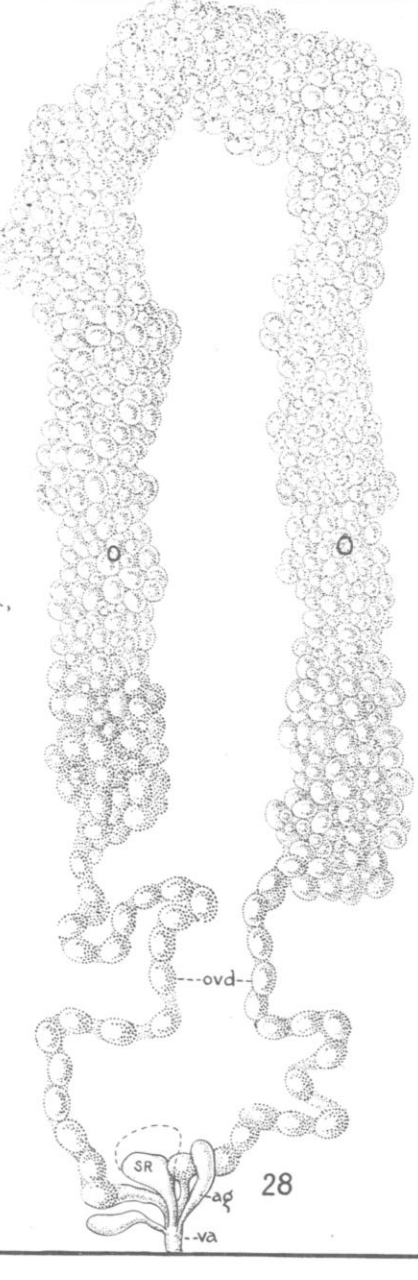

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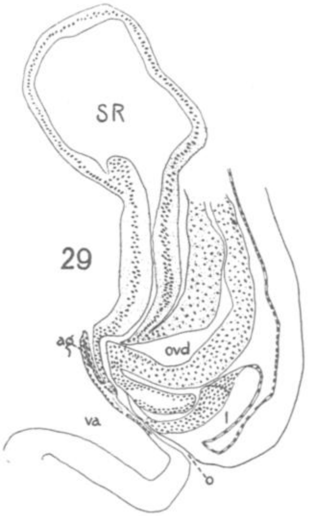

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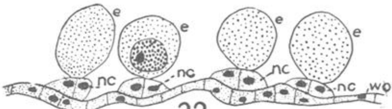
PLATE XXXI



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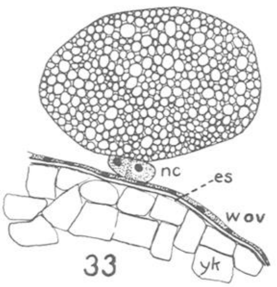

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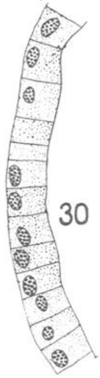

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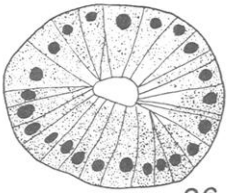

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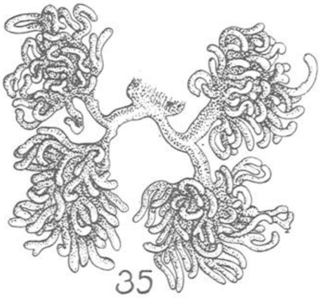

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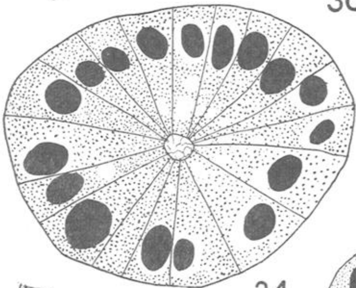

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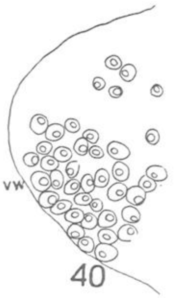

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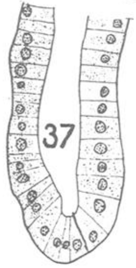

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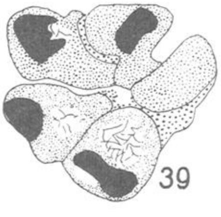

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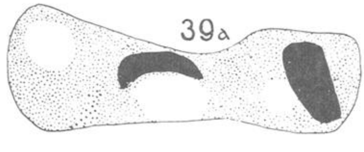

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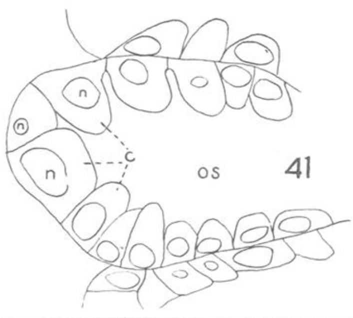

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